DACA42-02-C-0001

LOGANEnergy

Residence of Colonel Johnson PEM Demonstration Program
Fort Jackson, Columbia, South Carolina
Final Report

Proton Exchange Membrane (PEM) Fuel Cell Demonstration
Of Domestically Produced PEM Fuel Cells in Military Facilities

US Army Corps of Engineers
Engineer Research and Development Center
Construction Engineering Research Laboratory
Broad Agency Announcement CERL-BAA-FY01

Fort Jackson
Columbia, South Carolina

September 30, 2004

Executive Summary

LOGANEnergy Corporation has received a contract award from the US Army Corps of Engineers, Construction Engineering Research Lab to test and evaluate Proton Exchange Membrane (PEM) Fuel Cells at several DOD sites. Fort Jackson, SC is one of the sites that have been awarded to LOGAN. The main purpose of this program was to demonstrate the feasibility of obtaining a minimum of 90% availability over a one year period using a residential PEM fuel cell. The initial start-up of this PEM demonstration occurred on February 20, 2003.

The personal residence of Colonel Brent A. Johnson, the garrison commander, was chosen for the demonstration site. It hosts a 5kW, 120vac, GenSys SU-1 PEM technology demonstration unit manufactured by Plug Power Corporation, Latham, NY. The unit operates in a grid parallel / grid synchronized configuration at 2.5kW and is capable of operating in a grid independent/load following configuration in the event of a power failure. The unit is instrumented with an external wattmeter, temperature sensor, Btu meter, and a gas meter. A phone line is connected to the power plant communication's modem to call-out with alarms or events requiring service and attention.

The Point of Contact for this project is Wayne Shiely, Department of Logistics and Engineering, (803) 751-2708. The estimated total energy cost savings to Ft Jackson for participating in this demonstration project is $349.48.

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Proposal – Proton Exchange Membrane (PEM) Fuel Cell Demonstration of Domestically Produced Residential PEM Fuel Cells in Military Facilities

1.0 Descriptive Title

Residence of Colonel Brent A. Johnson PEM Demonstration Program, Fort Jackson, Columbia, South Carolina

2.0 Name, Address and Related Company Information

LOGANEnergy Corporation
1080 Holcomb Bridge Road
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Roswell, GA 30076

(770) 650- 6388

Data Universal Numbering System (DUNS) Number: 01-562-6211
Commercial and Government Entity (CAGE) Code: 09QC3
Taxpayer Identification Number (TIN): 58-2292769

LOGANEnergy Corporation is a private Fuel Cell Energy Services company founded in 1994. LOGAN specializes in planning, developing, and maintaining fuel cell projects. In addition, the company works closely with manufacturers to implement their product commercialization strategies. Over the past decade, LOGAN has analyzed hundreds of fuel cell applications. The company has acquired technical skills and expertise by designing, installing and operating over 30 commercial and small-scale fuel cell projects totaling over 7 megawatts of power. These services have been provided to the Department of Defense, fuel cell manufacturers, utilities, and other commercial customers. Presently, LOGAN supports 30 PAFC and PEM fuel cell projects at 21 locations in 12 states, and has agreements to install 22 new projects in the US and the UK over the next 18 months.

3.0 Production Capability of the Manufacturer

Plug Power manufactures a line of PEM fuel cell products at its production facility in Latham, NY. This facility, which opened in February 2000, is comprised of 50,000 square feet of dedicated production and production test facilities. The facility produces three lines of PEM products including the 5kW GenSys5C natural gas unit, the GenSys5P LP Gas unit, and the GenCor 5kW standby power system. The current facility has the capability of manufacturing 10,000 units annually.

Plug will support this project by providing remote monitoring, telephonic field support, overnight parts supply, and customer support. These services are intended to enhance the reliability and performance of the unit and achieve the highest possible customer satisfaction. Scott Wilshire is the Plug Power point of contact for this project. His phone number is 518.782.7700 ex1338, and his email address is scott_wilshire@plugpower.com.

4.0 Principal Investigator(s)

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6.0 Past Relevant Performance Information

a) Contract: PC25 Fuel Cell Service and Maintenance Contract #X1237022

Merck & Company
Ms. Stephanie Chapman
Merck & Company
Bldg 53 Northside
Linden Ave. Gate
Linden, NJ 07036
(732) 594-1686

Contract: Four-year PC25 PM Services Maintenance Agreement.
In November 2002 Merck & Company issued a four-year contract to LOGAN to provide fuel cell service, maintenance and operational support for one PC25C fuel cell installed at their Rahway, NJ plant. During the contract period the power plant has operated at 94% availability. LOGAN performs the quarterly and annual service prescribed by UTC, and performs other maintenance as required. The periods of unavailability are chiefly due to persistent inverter problems that seem to be endemic to the Toshiba power conditioning system. Field modifications and operating adjustments have largely cured the problem. Quarterly service events take 10 hours to complete with the unit under load, and the annual event takes approximately 35 hours with the unit shut down.

b) Contract: Plug Power Service and Maintenance Agreement to support one 5kWe GenSys 5C and one 5kWe GenSys 5P PEM power plant at NAS Patuxant River, MD.

Plug Power

Mr. Scott Wilshire.
968 Albany Shaker Rd.
Latham, NY 12110
(518) 782-7700 ex 1338

LOGAN performed the start-up of both units after Southern Maryland Electric Cooperative completed most of the installation work. The units are located at residential sites at Patuxant River Naval Air Station, VA and operate in standard gird connected/grid independent configurations. Both operate at 4.5kWe and have maintained 98% availability. The units, S/Ns 241 and 242 are two of the very latest GenSys models to reach the field. S/N 242 is Plug Power's first LPG fueled system to go into the field. Both have set a new level of performance expectations for this product, and are indicative of the success of the various test and evaluation programs that have been conducted over the past two years.

c) Contract: A Partners LLC Commercial Fuel Cell Project Design, Installation and 5-year service and maintenance agreement.
Contract # A Partners LLC, 12/31/01

Mr. Ron Allison
A Partners LLC
1171 Fulton Mall
Fresno, CA 93721
(559) 233-3262

On April 20, 2004 LOGAN completed the installation of a 600kWe PC25C CHP fuel cell installation in Fresno, CA. The system operating configurations allow for both grid parallel and grid independent energy service. The grid independent system is integrated with a multi unit load sharing electronics package and static switch, which initial development was funded by ERDC CERL in 1999. This is the fifth fuel cell installation that uses the MULS System. The thermal recovery package in the project includes a 100-ton chiller that captures 210 degree F waste heat supplied by the three fuel cells to cool the first three floors of the host facility. The fuel cells also provide low-grade waste heat at 140 degrees F that furnishes thermal energy to 98 water source heat pumps located throughout the 12-story building during the winter months.

7.0 Host Facility Information

Fort Jackson, located in Columbia, South Carolina is home to the largest and most active Initial Entry Training Center in the United States Army. It provides basic combat training for half of all Army Soldiers and 69 percent of all female Soldiers entering the United States Army. There are more than 52,000 acres and 53 ranges and field training sites. Fort Jackson supports several other training missions, including two Advanced Individual Training schools, the United States Army Soldier Support Institute, the United States Army Chaplain Center and School, and the Department of Defense Polygraph Institute.

The fort was established on June 2, 1917 as an Army Training Center in response to the need for trained men in World War I. It was first known as the Sixth National Cantonment out of the sixteen designated to support the war effort, and later renamed as Camp Jackson, in honor of Major General Andrew Jackson.

Fort Jackson's utility provider is South Carolina Electric and Gas who provides both electricity and natural gas to the base. City water is provided to the base by the City of Columbia.

8.0 Fuel Cell Installation

In February 2002, DCH Enable, the fuel cell manufacturer originally contracted to supply the fuel cell at Fort Jackson, notified LOGAN that they would not be able to fill the order. Fortunately, Plug Power agreed to provide a fuel cell, and LOGAN subsequently contracted with Plug to supply a 5kW GenSys5C for the Fort Jackson project.

In mid August 2002, LOGAN and CERL personnel met at Fort Jackson to discuss the demonstration project with Jerry Fuchs and Colonel Johnson, the garrison commander. During the discussion, Colonel Johnson volunteered his personal residence to be the installation site. The Colonels home is a one story, wood frame, ranch house with attached car port. After a brief visit to his residence, it was decided to accept his offer to install the fuel cell there. Figure 1 and Figure 2 are photos of the fuel cell on its pad at Col. Johnson's residence. The back yard and patio are open to the right of the fuel cell.

Natural gas is conveniently located within 25 feet of the fuel cell pad, and the residential equipment room housing the hot water heater, electrical panel, and make-up water source are also close and accessible.

Figure 1, at right, is a view of the installation showing the fuel cell sitting on a pad previously occupied by a 2-ton residential air conditioning unit. The fuel cell was rigged onto the pad with the assistance of a commercial fork truck. Note the compost bin to the right of the fuel cell. A small section of fence and some screening shrubbery were later placed in front of the fuel cell.

Figure 1

Figure 2

The installation phase of the project began in October of 2002. The installation was delayed when the original subcontractor hired to install the fuel cell did not perform satisfactory and had to be replaced. The initial start of the Fort Jackson unit occurred on February 20, 2003. Figure 3, below, diagrams the fuel cell installation with utility interfaces including, natural gas, electrical panel and make-up water in the adjacent residential room. The natural gas piping run from the gas meter to the fuel cell is approximately 25 feet. From the make-up water reverse osmosis unit to the fuel cell is also approximately 25 feet, and the electrical and thermal recovery conduit runs are approximately 25 feet.

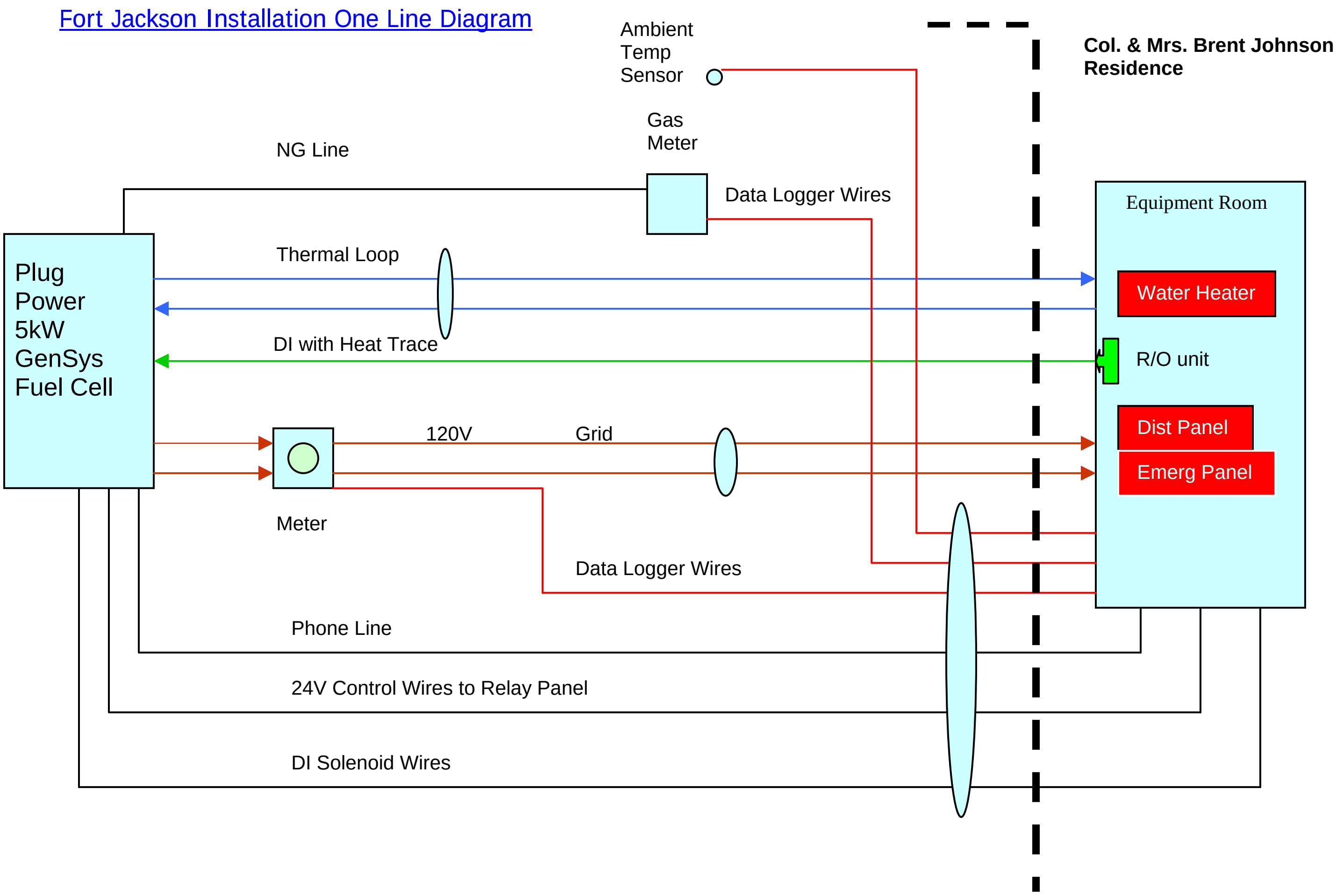

Figure 3

A Reverse Osmosis water filtration system was installed in the equipment room to provide filtered process water to the power plant. Make-up water was piped to the fuel cell as indicated in Figure 3, above, and the piping heat traced to prevent freezing.

The LOGAN field technician spent 27 hours on site during the installation phase of the project. This time was spent preparing the site for installation, supervising the electrical and plumbing contractor, and meeting with Fort Jackson personnel. The actual start-up of the fuel cell required 23 hours.

The project required the procurement of two construction permits. A digging permit was issued by Fort Jackson, and air quality permit was issued by the South Carolina Department of Health and Environment. Fort Jackson personnel performed an asbestos investigation prior to allowing the project to begin. The differential between the estimated and the actual costs to install this project was not significant.

9.0 Electrical System

The fuel cell inverter in the GenSys S/N 161 fuel cell is the new MP-5, which adds a grid independent operating configuration to the grid parallel basic service for the first time in a Plug Power fuel cell. In addition to the ability to operate in parallel to the utility grid this fuel cell is able to power a separate electrical panel in the event of a grid failure. This capability is an important milestone in the development of the Gensys5 product and for the PEM Program itself, as it is a significant developmental step on the pathway to product commercialization.

In order to take full advantage of the improved inverter capabilities, LOGAN installed a two-pole wattmeter to record power delivered to both the existing power panel and the new critical load panel installed in the equipment room seen in Figure 6 below. In the event of a power failure the new critical load panel would be powered by the fuel cell. Small non-critical electric outlets in the kitchen were transferred over to this panel to simulate the application. Some of these outlets provide power to the microwave oven, the toaster, and a light switch. In addition LOGAN installed a two-pole safety disconnect switch that permits the technician to safely bypass the fuel cell for maintenance without causing an inconvenience to the occupants of the residence. A schematic diagram of the disconnect switch necessary for the dual configuration MP5 inverter appears in Figure 4 below. The unit has a power output of 110/120 VAC at 60 Hz, matching the residential distribution panel in the mechanical room with its connected loads at 110/120 VAC.

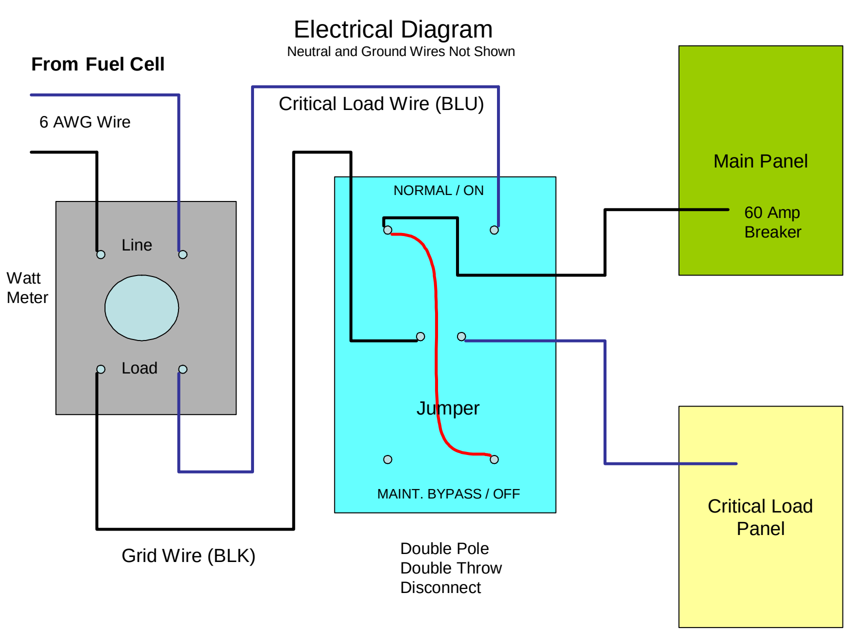

Figure 4

10.0 Thermal Recovery System

A Bradford White 80 gallon Combi-Coil hot water tank with an internal heating coil replaced the existing 40 gallon natural gas only hot water tank so that fuel cell waste heat could be provided to the residence thermal loads. These loads were fairly small and consisted of typical residential domestic hot water loads such as dishwashing, clothes washing, and showers.

While operating at a set point of 2.5 kWh, the fuel cell provides 11,200 Btuh to the storage tank at approximately 140 degrees F. Fuel Cell waste heat circulates between the fuel cell heat exchanger and the new hot water tank seen in the photo in Figure 5. The small pump, pictured at right, circulates a glycol solution between the fuel cell's heat exchanger and the hot water tank. This action transfers the fuel cell's waste heat into the tank as it flows through the coils wrapped around the tank.

A BTU meter, seen in Figure 6 below, monitors the output of heat transferred into the thermal recovery system. The photo also shows the several other components that make up the thermal recovery system at this site.
These components, generally needed on most PEM fuel cell thermal recovery systems, include an expansion tank, an air bleed valve, and a pressure regulator.

Circulating Pump

Figure 5

The external thermal recovery loop on Plug Power GenSys fuel cells should be designed to meet the following specifications:

- Flow: 0-10 gpm (1-2 gpm will maximize heat reclamation from the fuel cell)
- Pressure: <= 30 psig
- Temperature: (installation specific) with a flow rate of 1-2 gpm, the return temperature to the customer-supplied system will be approximately 140^{o}F
- Available heat:
    - 11,200 BTU/hr @ 2.5kWe
    - 21,900 BTU/hr @ 4.0kWe
    - 27,000 BTU/hr @ 5.0kWe

11.0 Data Acquisition System Figure 6

Fuel Cell CL, 24V Relay, Btu Meter & Data Logger

During the period October 2002 to August 2003, LOGAN's field service technicians performed their tasks with the support of a very rudimentary Supervisory Control and Data Acquisition (SCADA) system developed by Plug Power for communicating with deployed units. This system provided one-way communication from each unit to Plug's customer support center, allowing the unit to call in overnight to download a data package and an operating status report. However, LOGAN realized very quickly that the system was inadequate and unreliable to provide the high level of communications support needed for its wide-ranging PEM demonstration program. At times a unit called in and provided only partial data or incorrect data. This created uncertainty in troubleshooting and further delay in restoring units to service. On other occasions a unit might fail to call in for a week or more. While both Plug and LOGAN struggled early in the learning curve experience in developing cooperative service norms, the weakness of the SCADA system became a major source of dissatisfaction with Plug Power. Under the circumstances the only means of determining a unit's actual status was to make a service call to the site. However, the scope of LOGAN's PEM program required a better solution. Finally, in March 2003 an event occurred that gave Plug direct insight into the shortcomings of its SCADA system. After advising of a shutdown at Fort Bragg, Plug sent its own technician to the site because LOGAN's technicians were servicing other units. The technician flew from Albany, NY to Raleigh, NC and then drove out to the site. Upon arriving, the technician discovered that the unit was operating normally. Indeed the SCADA system was not.

This event was an important turning point for the LOGAN/Plug Power relationship and its cooperative efforts in achieving the goals of the PEM Demonstration Program. Six weeks later in early June, six representatives from LOGAN and eight from Plug Power met in Atlanta for two days of forthright discussions. The meeting focused on short-term methods and longer term solutions to improve remote PEM fuel cell performance. Most significantly Plug determined that it would institute immediate software changes and upgrades to insure the accuracy of fuel cell data communications. Plug also promised to initiate a design change to its SCADA system that would permit bi-directional remote communications with the fuel cell controller. More importantly Plug promised that LOGAN's technicians would be able to remotely troubleshoot, change set points and attempt restarts under some circumstances. Lastly they also promised that they would publish a daily status report covering all of LOGAN's units. By early August Plug began sending daily status reports, and by mid September Plug shipped LOGAN's technician's new control software that permits remote diagnostics, monitoring, troubleshooting, and restart capabilities. Since the introduction of this new service capability along with the adoption of improved service techniques to go with it, fleet performance, availability and operating costs have begun to show positive new trends.

An external four-channel data-logger, pictured in Figure 6 above, was installed at the site to record natural gas usage, kW output, outside air temperature, and Btu output from the fuel cell.

12.0 Fuel Supply System

Gas supply flows from a gas meter adjacent to the fuel cell pad as indicated in Figure 3. A regulator installed at the fuel cell gas inlet maintains the correct operating pressure at 10-14 inches water column (IWC). A new gas meter installed on the fuel cell supply records the gas volume consumed by the fuel cell. A pulse signal is sent from the natural gas meter to the data logger. Natural gas is provided to the residence by the base and is not metered at the site by the gas company.

The Plug Power PEM fuel cell natural gas requirements are:

- Must be >90% methane
- No greater than 15 ppm sulfur on a yearly average basis
- Supply Pressure: 4” to 11” water column
- Maximum flow rate: 105,000 btu/hr
- Nominal flow rate: 72,700 btu/hr

12.0 Program Costs

Fort Jackson PEM Demonstration Program

Project Utility Rates					
1) Water (per 1,000 gallons)		$	1.31		
2) Utility (per KWH)		$	0.065		
3) Natural Gas (per MCF)		$	5.80		
First Cost				**Estimated**	**Actual**
Plug Power 5 kW SU-1				$ 75,000.00	$ 75,000.00
Shipping				$ 1,800.00	$ 1,500.00
Installation electrical				$ 4,200.00	$ 2,182.00
Installation mechanical & thermal				$ 3,600.00	$ 6,500.00
Watt Meter, Instrumentation, Web Package				$ 800.00	$ 673.00
Site Prep, labor materials				$ 925.00	$ 1,024.00
Technical Supervision/Start-up				$ 6,500.00	$ 5,347.00
Total				**$ 92,825.00**	**$ 92,226.00**
Assume Five Year Simple Payback				$ 18,565.00	$ 18,445.20
Forcast Operating Expenses	Volume		$/Hr	$/ Yr	
Natural Gas Mcf/ hr @ 2.5kW	0.0328	$	0.19	$ 1,501.59	
Water Gallons per Year	14,016			$ 18.36	
Total Annual Operating Cost					$ 1,519.95
Economic Summary					
Forcast Annual kWH			19710		
Annual Cost of Operating Power Plant		$	0.077	kWH	
Credit Annual Thermal Recovery		$	(0.030)	kWH	
Project Net Operating Cost		$	0.047	kWH	
Displaced Utility cost		$	0.065	kWH	
Energy Savings			$0.018	kWH	
Annual Energy Savings			$349.48		

Explanation of Calculations:

Actual First Cost Total is a *sum* of all the listed first cost components.

Assumed Five Year Simple Payback is the Estimated First Cost Total *divided by* 5 years.

Forecast Operating Expenses:

Natural gas usage in a fuel cell system set at 2.5 kW will consume 0.033 Mcf per hour. The cost per hour is 0.033 Mcf per hour *x* the cost of natural gas to Jackson per Mcf at $5.80. The cost per year at $1501.59 is the cost per hour at $0.19 *x* 8760 hours per year *x* 0.9. The 0.9 is for 90% availability.

Natural gas fuel cell systems set at 2.5 kW will consume 1.6 gallons of water per hour through the DI panel. The total volume of water consumed at 14,016 gallons per year is 1.6 gph *x* 8760 hours per year. The cost per year at $18.36 is 14,016 gph *x* cost of water to Jackson at $1.31 per 1000 gallons.

The Total Annual Operating Cost, $1519.95 is the *sum of* the cost per year for the natural gas and the cost per year for the water consumption.

Economic Summary:

The Forecast Annual kWh at 19,710 kWh is the product of 2.5 kW set-point for the fuel cell system *x* 8760 hours per year *x* 0.9. The 0.9 is for 90% availability.
The Annual Cost of Operating the Power Plant at $0.077 per kWH is the Total Annual Operating Cost at $1519.95 *divided by* the forecast annual kWh at 19,710 kWh.
The Credit for Annual Thermal Recovery of $0.018/kWH equals 7800 BTU per hour thermal recovery at 2.5 kW *divided* by 3414BTU/kWh *multiplied* .20 recovery factor, *multiplied* by $0.039/kWh. As a credit to the cost summary, the value is expressed as a negative number.
The Project Net Operating Cost is the *sum* of the Annual Cost of Operating the Power Plant *plus* the Credit Annual Thermal Recovery.
The Project Net Operating Cost is the *sum* of the Annual Cost of Operating the Power Plant *plus* the Credit Annual Thermal Recovery.
The Displaced Utility Cost is the kWh cost of electricity paid by Ft. Jackson.

Energy Savings (cost) equals the Displaced Utility Cost *minus* the Project Net Operating Cost.

Annual Energy Savings (cost) equals the Energy Savings *x* the Forecast Annual kWh.

14.0 Milestones/Improvements

The GenSys Residential PEM fuel cell was placed on its pad on October 17, 2002. The first successful eight hour run of the fuel cell took place on February 24, 2003. This power plant experienced six unplanned shutdowns during the 12 month demonstration. The fuel cell had only two planned shutdowns during the demonstration because most preventative maintenance (PM) was performed during the unplanned shutdowns. The fuel cell demonstration was successfully completed on March 4, 2004

Over the course of the 12 month demonstration the fuel cell was available over 96% of the time. This is a significant improvement over previous demonstrations. This improvement can be attributed to improvements in the fuel cell design by Plug Power and improved maintenance expertise on the part of LOGANEnergy field technicians. The fuel cell had no shut downs for the last three months of the demonstration.

15.0 Decommissioning/Removal/Site Restoration

On March 7, 2004, three days after the completion of the demonstration the piping from the fuel cell to equipment room located on the side of the car port was hit by a car. No one was hurt and the fuel cell was undamaged but the electrical conduit and thermal recovery piping was badly damaged. The fuel cell shut off and was not restarted.

The fuel cell was decommissioned the week of March 8^{th}. The fuel cell was subsequently shipped to the Department of Defense Fuel Cell Test and Evaluation Center in Johnstown, Pennsylvania. There it will be installed at their 50 Circuit Home Simulator System and undergo additional testing.

16.0 Additional Research/Analysis

On July 30, 2003, SCANA Corporation, the local electric utility, used a Harmonic Meter to measure the harmonics of the existing electrical system at the Fort Jackson PEM fuel cell demonstration site. The results of their test are attached. See Appendix 3. (Harmonic readings are proprietary).

17.0 Conclusions/Summary

In conclusion, the PEM fuel cell demonstration at Fort Jackson should be considered by all involved a great success. The availability benchmark of this unit equaled that of much more mature power generation technologies.

As the fuel cell industry continues to move towards a fully commercial residential PEM fuel cell; demonstrations of this type will contribute valuable information related to the real world application of this technology. Installation, operation and maintenance experience can be incorporated into future designs of fuel cells making them easier and cheaper to install and maintain.

Appendix

1) Monthly Performance Data

2) Daily Work Logs

3) Monthly Performance Data